



Seasonal Patterns of Ants (Hymenoptera: Formicidae) in Punjab Shivalik

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Abstract

Seasonal patterns of Ants were analysed in five seasons in Punjab Shivalik range of North-West Himalaya. Various collection methods like Pitfall traps, Winkler's, Fish bait and Hand picking were used. 40 species belonging to 8 subfamilies have been observed for seasonal patterns and subfamily Myrmicinae followed by Formicinae were found to be dominant. Temperature and Relative humidity have been correlated with seasonal patterns.

Keywords: Seasonal patterns, Ants, Shivalik, Disturbed ecosystem, Anthropogenic activity, North-West Himalaya.

Introduction

Various studies have been carried on community composition on ants, their habitats, foraging behaviour and other ecological aspects. However, studies dealing specifically with seasonal patterns of ants are comparatively few. To start with, Davidson (1977) studied foraging ecology and community organisation in desert seed-eating ants. Levings (1983) studied the seasonal, annual and site variations in the ground ant communities of a tropical forest. Zorilla *et al.* (1986), while studying structural characteristics of an ant community during succession observed that ant communities in the pastures present a sequence of successional variation. Andersen (1986) worked on diversity, seasonality in ant community organisation of ants at woodland site in South-eastern Australia.

Fellers (1989) observed daily seasonal activity in woodland ants. Johnson (1992)

monitored seasonal structure of ant communities. Belshaw and Bolton (1993) studied the effect of forest disturbance on leaf litter ant fauna and concluded that most primary forest leaf litter ant species continue to survive in parts of the agricultural landscape which has largely replaced their original habitat. Byrne (1994) observed the correlation between availability of nests and soil type. Fellowes (1996) discussed community composition of Hong Kong ants with respect to spatial and seasonal patterns. Smith *et al.* (1997) studied variation in structure and function of ant communities during stress and disturbance. Rico-Gray *et al.* (1998) observed richness and seasonal variation of ant-plant association mediated by plant derived resources in Mexico. Whitford (1999) studied seasonal and diurnal activity patterns in ant communities in vegetation transition region of New Mexico.

Retana and Cerda (2000) observed the patterns of diversity and composition of Mediterranean ground ant communities. Vanderwoude *et al.* (2000) observed long term ant communities responses to selective harvesting of timber from spotted forest in Southeast Queensland.

Clough (2004) worked on the factors influencing ant assemblages and ant community composition in a subtropical sub-urban environment and concluded that ant communities in sub-urban environments respond to disturbance in a similar manner to ant communities in tropical forest and rainforests. Touyama and Kameyama (2004) worked on foraging behavior with relation to temperature. Coelho and Ribeiro (2006) expressed the response of ant species assemblage to contrasting types of forests in Brazil. Recently, Basu (2008) analysed seasonal and spatial patterns in ground foraging ants and observed that all ant species showed marked seasonality. Suwabe *et al.* (2008) assessed difference in seasonal activity pattern between non-native and native ants in subtropical forest of Okinawa Island, Japan. With this state of affairs, the present study was aimed to generate knowledge about seasonal patterns of ant species in Punjab Shivalik.

The area chosen for study is a disturbed ecosystem, subject to anthropogenic activities. The Punjab Shivalik extends between river Ravi in north and river Ghaggar in south; (between latitude 30°34' 10.82" and 32°33' 02.95"N; longitude 74°50' 30.30" and 76° 57.26"E). The Punjab Shivalik is about 280 km long with variable width of 5 km to 12 km. The Shivalik experiences koeppen's cwg category climate (Mittal *et al.*, 2000) based on annual and monthly means of temperature and rainfall. This is characterized by humid, tropical and dry winter, extreme seasonal temperatures, long dry-short wet season and potential

evapotranspiration exceeding precipitation, which varies from 800 to 1200 mm annually.

The Punjab Shivalik falls in the sub-moist to humid and less hot region. The temperature in the area varies from about 2°C in winters to a maximum of about 42°C in summers, and the annual rainfall varies between 400 to 600 mm (Tiwana and Jerath, 2006). Champion and Seth (1968) categorised the forests of Punjab Shivalik into following types: 1. Northern dry mixed deciduous forests, 2. Chir-Pine Forests, 3. Dry deciduous scrub forests, 4. Khair and *Dalbergia* *sissu* forests, 5. Dry Bambo brakes, 6. Subtropical *Euphorbia* scrub. On the basis of texture, climate, topography and denudational process, the soil of Punjab Shivalik is divided into following types: 1. Grey-Brown Podgolic and Fores soil, 2. Kandi soil.

Materials and Methods

For collection of ants different sites (Talwara, Hajipur, Chohal, Ropar, Pathankot, Jugial) falling in Punjab Shivalik were visited. The selected sites were visited frequently/ repeatedly so as to cover different seasons of the year and five seasons are recognised in the state of Punjab (Mavi and Tiwana, 1993);

Summer season	:	Mid April to end of June
Rainy season	:	Early July to September
Autumn season	:	September to end of November
Winter season	:	Early December to end of February
Spring season	:	March to Mid April

For collection of ants following methods were used: Pitfall traps were placed, made up of test tubes (with an 18mm internal diameter and 150mm long) partly filled to a depth of about 50mm with soapy water and 5% ethylene glycol solution. Leaf litter samples were sifted in a

1 m × 1 m quadrant, every 5 meter along the transect using a litter sifter through a wire sieve with square holes of 1 cm × 1 cm and placed in mini Winkler’s sac (Fisher, 2004). Ants were then extracted after 48 hours. Ants were also collected by hand picking method i.e. searching logs, stumps, dead and live branches, twigs, low vegetation, termite mounds and under stones.

To increase the effectiveness of this study sampling sites were chosen interior into forest. Temperature and Relative humidity of the

above mentioned areas were recorded during different seasons of the year. Collected specimens were preserved in 70% alcohol to prevent degradation. The collected specimens were mounted on triangles, as per standard procedure in ant taxonomy. Dry specimens bearing all relevant data are kept in wooden boxes. For identification, Bolton (1994) and Bingham (1903) were followed and the identified material was compared with reference collection housed in the laboratory.

Table-1: (List of species collected during Summer Season)

Subfamilies	Genus	Name of Species
Myrmicinae	<i>Pheidole</i>	<i>Pheidole latinoda angustior</i> Forel <i>Pheidole indica</i> Mayr <i>Pheidole spathifera aspatha</i> Forel
	<i>Meranoplus</i>	<i>Meranoplus bicolor</i> (Guerin-Meneville)
	<i>Myrmicaria</i>	<i>Myrmicaria brunnea brunnea</i> Saunders
	<i>Tetramorium</i>	<i>Tetramorium walshi</i> (Forel)
	<i>Monomorium</i>	<i>Monomorium criniceps</i> (Mayr) <i>Monomorium glabrum</i> (Andre) <i>Monomorium destructor</i> (Jerdon) <i>Monomorium pharaonis</i> (Linnaeus) <i>Monomorium indicum indicum</i> Forel
	<i>Messor</i>	<i>Messor instabilis</i> (Smith, F.)
	<i>Crematogaster</i>	<i>Crematogaster subnuda subnuda</i> Mayr
Ponerinae	<i>Pachycondyla</i>	<i>Pachycondyla luteipes luteipes</i> (Mayr) <i>Pachycondyla tesseronoda</i> (Emery) <i>Pachycondyla bispinosa</i> Smith, F. <i>Pachycondyla nigrita nigrita</i> (Emery) <i>Pachycondyla rufipes rufipes</i> (Jerdon)
	<i>Harpegnathos</i>	<i>Harpegnathos venator venator</i> (Smith, F.)
	<i>Leptogenys</i>	<i>Leptogenys diminuta laeviceps</i> (Smith, F.)
	<i>Odontoponera</i>	<i>Odontoponera transversa transversa</i> (Smith, F.)

Table-1: Continued

Subfamilies	Genus	Name of Species
Cerapachyinae	<i>Cerapachys</i>	<i>Cerapachys longitarsus</i> (Mayr)
Formicinae	<i>Oecophylla</i>	<i>Oecophylla smaragdina smaragdina</i> (Fabricius)
	<i>Lepisiota</i>	<i>Lepisiota frauenfeldi integra</i> (Forel) <i>Lepisiota opaca pulchella</i> (Forel)
	<i>Cataglyphis</i>	<i>Cataglyphis setipes</i> (Forel)
	<i>Camponotus</i>	<i>Camponotus parius</i> Emery <i>Camponotus compressus compressus</i> (Fabricius) <i>Camponotus rufoglaucus rufoglaucus</i> (Jerdon) <i>Camponotus sericeus sericeus</i> (Fabricius)
	<i>Polyrhachis</i>	<i>Polyrhachis lacteipennis lacteipennis</i> Smith, F.
	<i>Paratrechina</i>	<i>Paratrechina longicornis longicornis</i> (Latreille)
Dolichoderinae	<i>Bothriomyrmex</i>	<i>Bothriomyrmex wroughtonii wroughtonii</i> Forel
	<i>Tapinoma</i>	<i>Tapinoma melanocephalum melanocephalum</i> (Fabricius)
	<i>Chronoxenus</i>	<i>Chronoxenus myops</i> (Forel)
Dorylinae	<i>Dorylus</i>	<i>Dorylus orientalis orientalis</i> Westwood <i>Dorylus labiatus</i> Schuckard
Aenictinae	<i>Aenictus</i>	<i>Aenictus pachycerus pachycerus</i> (Smith, F.)
Pseudomyrmecinae	<i>Tetraponera</i>	<i>Tetraponera allaborans</i> (Walker) <i>Tetraponera rufonigra</i> (Jerdon)

Table-2: (List of species collected during Rainy Season)

Subfamilies	Genus	Name of Species
Myrmicinae	<i>Pheidole</i>	<i>Pheidole latinoda angustior</i> Forel <i>Pheidole indica</i> Mayr <i>Pheidole spathifera aspatha</i> Forel
		<i>Meranoplus bicolor</i> (Guerin-Meneville)
	<i>Myrmicaria</i>	<i>Myrmicaria brunnea brunnea</i> Saunders
	<i>Tetramorium</i>	<i>Tetramorium walshi</i> (Forel)
	<i>Monomorium</i>	<i>Monomorium criniceps</i> (Mayr) <i>Monomorium glabrum</i> (Andre) <i>Monomorium destructor</i> (Jerdon) <i>Monomorium pharaonis</i> (Linnaeus) <i>Monomorium indicum indicum</i> Forel

Table-2: Continued

Subfamilies	Genus	Name of Species
	<i>Messor</i>	<i>Messor instabilis</i> (Smith, F.)
	<i>Crematogaster</i>	<i>Crematogaster subnuda subnuda</i> Mayr
Ponerinae	<i>Pachycondyla</i>	<i>Pachycondyla luteipes luteipes</i> (Mayr) <i>Pachycondyla tesseronoda</i> (Emery) <i>Pachycondyla bispinosa</i> Smith, F. <i>Pachycondyla nigrita nigrita</i> (Emery) <i>Pachycondyla rufipes rufipes</i> (Jerdon)
	<i>Harpegnathos</i>	<i>Harpegnathos venator venator</i> (Smith, F.)
	<i>Leptogenys</i>	<i>Leptogenys diminuta laeviceps</i> (Smith, F.)
	<i>Odontoponera</i>	<i>Odontoponera transversa transversa</i> (Smith, F.)
Cerapachyinae	<i>Cerapachys</i>	<i>Cerapachys longitarsus</i> (Mayr)
Formicinae	<i>Oecophylla</i>	<i>Oecophylla smaragdina smaragdina</i> (Fabricius)
	<i>Lepisiota</i>	<i>Lepisiota frauenfeldi integra</i> (Forel) <i>Lepisiota opaca pulchella</i> (Forel)
	<i>Cataglyphis</i>	<i>Cataglyphis setipes</i> (Forel)
	<i>Camponotus</i>	<i>Camponotus parius</i> Emery <i>Camponotus compressus compressus</i> (Fabricius) <i>Camponotus rufoglaucus rufoglaucus</i> (Jerdon) <i>Camponotus sericeus sericeus</i> (Fabricius)
	<i>Polyrhachis</i>	<i>Polyrhachis lacteipennis lacteipennis</i> Smith, F.
	<i>Paratrechina</i>	<i>Paratrechina longicornis longicornis</i> (Latreille)
Dolichoderinae	<i>Bothriomyrmex</i>	<i>Bothriomyrmex wroughtonii wroughtonii</i> Forel
Dorylinae	<i>Tapinoma</i>	<i>Tapinoma melanocephalum melanocephalum</i> (Fabricius)
	<i>Dorylus</i>	<i>Dorylus orientalis orientalis</i> Westwood <i>Dorylus labiatus</i> Schuckard
Aenictinae	<i>Aenictus</i>	<i>Aenictus pachycerus pachycerus</i> (Smith, F.)
Pseudomyrmecinae	<i>Tetraponera</i>	<i>Tetraponera allaborans</i> (Walker) <i>Tetraponera rufonigra</i> (Jerdon)

Table-3: (List of species collected during Autumn Season)

Subfamilies	Genus	Name of Species
Myrmicinae	<i>Pheidole</i>	<i>Pheidole latinoda angustior</i> Forel <i>Pheidole indica</i> Mayr <i>Pheidole spathifera aspatha</i> Forel
	<i>Meranoplus</i>	<i>Meranoplus bicolor</i> (Guerin-Meneville)
	<i>Myrmicaria</i>	<i>Myrmicaria brunnea brunnea</i> Saunders
	<i>Tetramorium</i>	<i>Tetramorium walshi</i> (Forel)
	<i>Monomorium</i>	<i>Monomorium criniceps</i> (Mayr) <i>Monomorium glabrum</i> (Andre) <i>Monomorium destructor</i> (Jerdon) <i>Monomorium pharaonis</i> (Linnaeus) <i>Monomorium indicum indicum</i> Forel
	<i>Messor</i>	<i>Messor instabilis</i> (Smith, F.)
	<i>Crematogaster</i>	<i>Crematogaster subnuda subnuda</i> Mayr
Ponerinae	<i>Pachycondyla</i>	<i>Pachycondyla luteipes luteipes</i> (Mayr) <i>Pachycondyla tesseronoda</i> (Emery) <i>Pachycondyla bispinosa</i> Smith, F. <i>Pachycondyla nigrita nigrita</i> (Emery) <i>Pachycondyla rufipes rufipes</i> (Jerdon)
	<i>Leptogenys</i>	<i>Leptogenys diminuta laeviceps</i> (Smith, F.)
	<i>Odontoponera</i>	<i>Odontoponera transversa transversa</i> (Smith, F.)
Formicinae	<i>Oecophylla</i>	<i>Oecophylla smaragdina smaragdina</i> (Fabricius)
	<i>Lepisiota</i>	<i>Lepisiota frauenfeldi integra</i> (Forel) <i>Lepisiota opaca pulchella</i> (Forel)
	<i>Cataglyphis</i>	<i>Cataglyphis setipes</i> (Forel)
	<i>Camponotus</i>	<i>Camponotus parius</i> Emery <i>Camponotus compressus compressus</i> (Fabricius) <i>Camponotus rufoglaucus rufoglaucus</i> (Jerdon) <i>Camponotus sericeus sericeus</i> (Fabricius)
	<i>Polyrhachis</i>	<i>Polyrhachis lacteipennis lacteipennis</i> Smith, F.
Dolichoderinae	<i>Bothriomyrmex</i>	<i>Bothriomyrmex wroughtonii wroughtonii</i> Forel

Table-3: Continued

Subfamilies	Genus	Name of Species
Tapinoma	Tapinoma	Tapinoma melanocephalum melanocephalum (Fabricius)
Dorylinae	Dorylus	Dorylus orientalis orientalis Westwood Dorylus labiatus Schuckard
Aenictinae	Aenictus	Aenictus pachycerus pachycerus (Smith, F.)
Pseudomyrmecinae	Tetraponera	Tetraponera allaborans (Walker) Tetraponera rufonigra (Jerdon)

Table-4: (List of species collected during Winter season)

Subfamilies	Genus	Name of Species
Myrmicinae	Monomorium	Monomorium destructor (Jerdon)
Formicinae	Camponotus	Camponotus compressus compressus (Fabricius)
	Paratrechina	Paratrechina longicornis longicornis (Latreille)
	Lepisiota	Lepisiota frauenfeldi integra (Forel)
Dolichoderinae	Tapinoma	Tapinoma melanocephalum melanocephalum (Fabricius)

Table-5: (List of species collected during Spring Season)

Subfamilies	Genus	Name of Species
Myrmicinae	Pheidole	Pheidole latinoda angustior Forel Pheidole indica Mayr Pheidole spathifera aspatha Forel
	Meranoplus	Meranoplus bicolor (Guerin-Meneville)
	Myrmicaria	Myrmicaria brunnea brunnea Saunders
	Tetramorium	Tetramorium walshi (Forel)
	Monomorium	Monomorium glabrum (Andre) Monomorium destructor (Jerdon) Monomorium pharaonis (Linnaeus) Monomorium indicum indicum Forel
	Messor	Messor instabilis (Smith, F.)
	Crematogaster	Crematogaster subnuda subnuda Mayr

Table-5: Continued

Subfamilies	Genus	Name of Species
Ponerinae	<i>Pachycondyla</i>	<i>Pachycondyla luteipes luteipes</i> (Mayr) <i>Pachycondyla tesseronoda</i> (Emery) <i>Pachycondyla bispinosa</i> Smith, F. <i>Pachycondyla nigrita nigrita</i> (Emery) <i>Pachycondyla rufipes rufipes</i> (Jerdon)
	<i>Leptogenys</i>	<i>Leptogenys diminuta laeviceps</i> (Smith, F.)
	<i>Odontoponera</i>	<i>Odontoponera transversa transversa</i> (Smith, F.)
Formicinae	<i>Oecophylla</i>	<i>Oecophylla smaragdina smaragdina</i> (Fabricius)
	<i>Lepisiota</i>	<i>Lepisiota frauenfeldi integra</i> (Forel) <i>Lepisiota opaca pulchella</i> (Forel)
	<i>Cataglyphis</i>	<i>Cataglyphis setipes</i> (Forel)
	<i>Camponotus</i>	<i>Camponotus parius</i> Emery <i>Camponotus compressus compressus</i> (Fabricius) <i>Camponotus rufoglaucus rufoglaucus</i> (Jerdon) <i>Camponotus sericeus sericeus</i> (Fabricius)
	<i>Polyrhachis</i>	<i>Polyrhachis lacteipennis lacteipennis</i> Smith, F.
	<i>Paratrechina</i>	<i>Paratrechina longicornis longicornis</i> (Latreille)
Dolichoderinae	<i>Bothriomyrmex</i>	<i>Bothriomyrmex wroughtonii wroughtonii</i> Forel
	<i>Tapinoma</i>	<i>Tapinoma melanocephalum melanocephalum</i> (Fabricius)

Table: 6 (Showing number of species collected w.r.t. temperature in different seasons of the year [2007-2008])

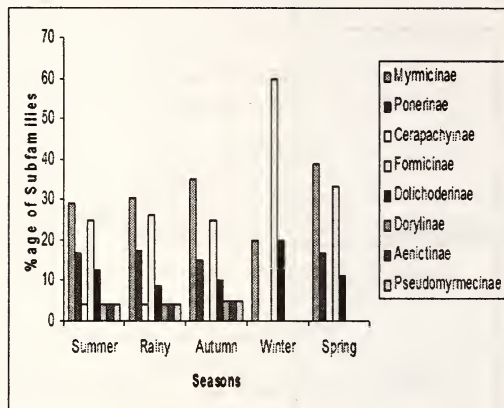
Seasons	Number of Species Collected	Temperature °C		Average temperature °C
		Maximum	Minimum	
Summer	40	36.54	20.81	28.67
Rainy	39	32.89	23.16	28.02
Autumn	36	31.6	16.4	24.0
Winter	5	19.6	2.26	10.93
Spring	31	20.63	19.08	19.85

Results and Discussion

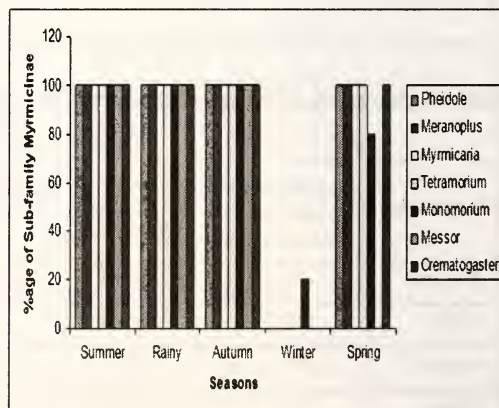
During the present study a total of 40 species have been recognised from Punjab Shivalik representing 8 subfamilies namely Myrmicinae, Ponerinae, Cerapachyinae, Formicinae, Dolichoderinae, Dorylinae, Aenictinae and Pseudomyrmecinae. Representatives of subfamilies Myrmicinae, Formicinae and Dolichoderinae were found throughout the year. These subfamilies were able to withstand extreme temperature fluctuation ranging from 2.26°C to 36.54°C (Table-6). All the 8 subfamilies were reported during summer season with Myrmicinae representing 29.16% of the total catch followed by Formicinae (25%) (Table-1, Graph-1). Dorylinae, Aenictinae and Pseudomyrmecinae were scanty. Rainy season was also dominated by subfamilies Myrmicinae and Formicinae. In autumn season, seven subfamilies were recorded, but no representative of subfamily Cerapachyinae was recorded. Extreme temperatures of winter were braved by subfamily Myrmicinae, Formicinae and Dolichoderinae. Within subfamily Myrmicinae genus *Monomorium* and species *Monomorium destructor* was the only representative that was found throughout the year. In subfamily Ponerinae, genus *Harpegnathos* was found only during summer and rainy season and no representative of Ponerinae was found in winter season. Similarly, subfamily Cerapachyinae was found only in summer and rainy season. Genus *Lepisiota*, *Camponotus* and *Paratrechina* of subfamily Formicinae were found throughout the year. Genus *Tapinoma* of subfamily Dolichoderinae was found in all the seasons of the year, whereas genus *Chronoxenus* was collected only during summer season. In subfamily Dorylinae, genus *Dorylus*, the only representative of the subfamily reported during this study was found missing in winter and spring season. Similarly, genus *Aenictus* (single representative) of subfamily Aenictinae was found in summer, rainy and autumn seasons. Genus *Tetraponera* representing subfamily Pseudomyrmecinae from Punjab Shivalik was

found only during summer, rainy and autumn seasons.

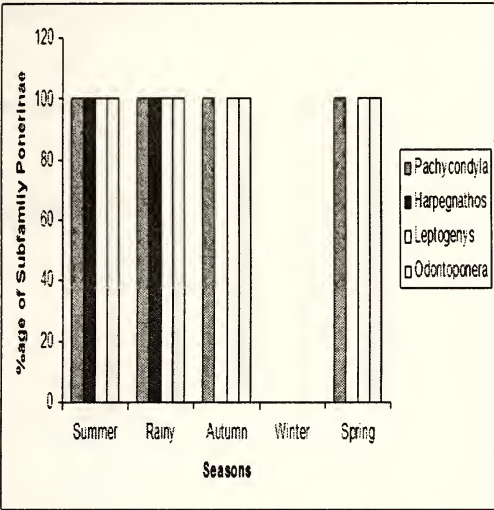
So, it can be concluded that species richness was maximum during summer season (36.54°C - 20.81°C), as a total of 40 species representing 24 genera and 8 subfamilies were collected during this season, whereas in winter season (19.6°C - 2.26°C) only 5 species belonging to subfamily Myrmicinae, Formicinae and Dolichoderinae were reported.



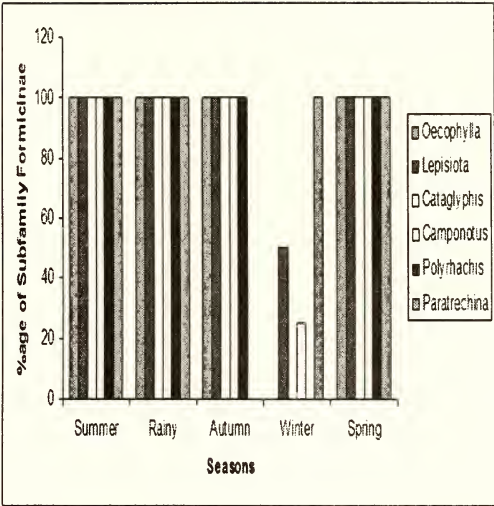
Graph-1: {Percentage representation of Subfamilies in different seasons of the year (2007-08)}



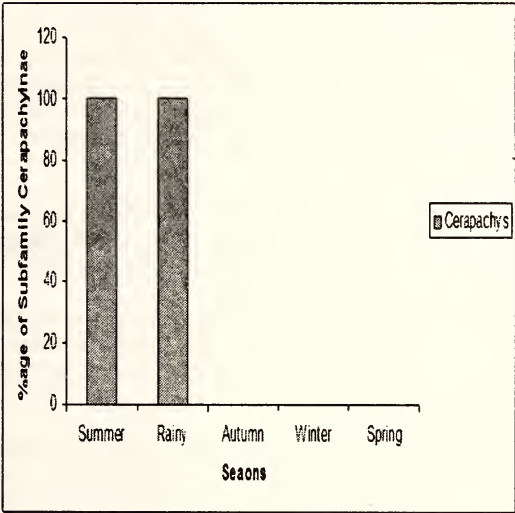
Graph-2: {Percentage representation of Subfamily Myrmicinae in different seasons of the year (2007-2008)}



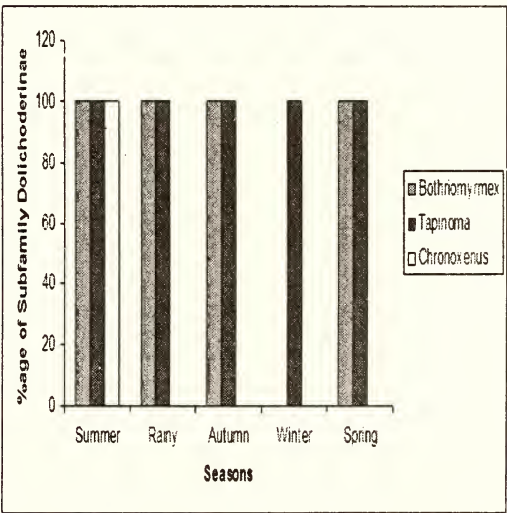
Graph-3: {Percentage representation of Subfamily Ponerinae in different seasons of the year (2007-2008)}



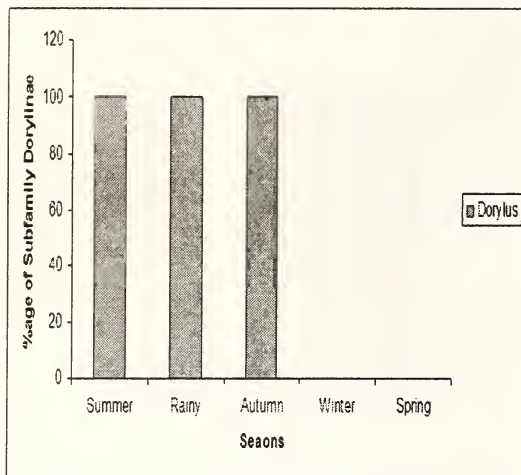
Graph-5: {Percentage representation of Subfamily Formicinae in different seasons of the year (2007-2008)}



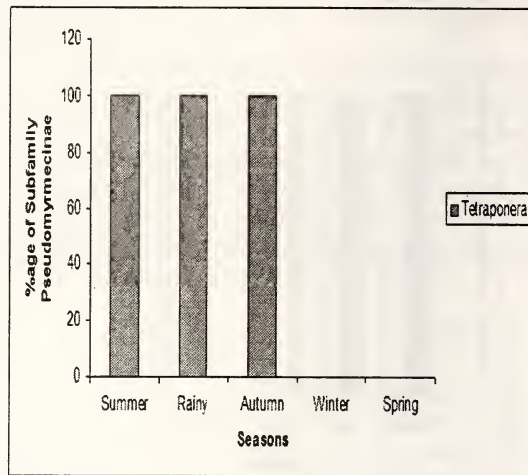
Graph-4: {Percentage representation of Subfamily Cerapachyinae in different season of the year (2007-2008)}



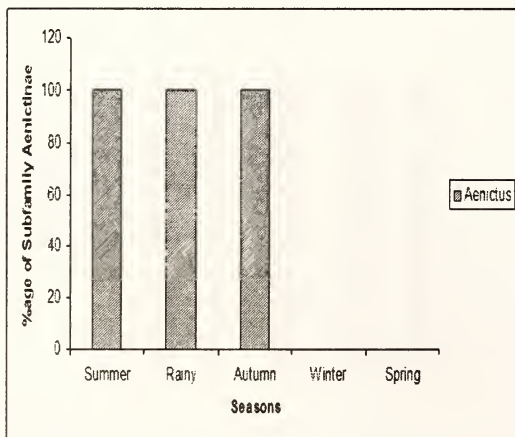
Graph-6: {Percentage representation of Subfamily Dolichoderinae in different season of the year (2007-2008)}



Graph-7: {Percentage representation of Subfamily Dorylinae in different seasons of the year (2007-2008)}



Graph-9: {Percentage representation of Subfamily Pseudomyrmecinae in different seasons of the year (2007-2008)}



Graph-8: {Percentage representation of Subfamily Aenictinae in different seasons of the year (2007-2008)}

References

- Andersen, A.N. 1986. Diversity, seasonality and community organization of ants at adjacent heath and woodland sites in South-Eastern Australia. *Australian Journal of Zoology* 34: 53-64.
- Basu, P. 2008. Seasonal and spatial patterns in ground foraging ants in a rain forest in the Western Ghats, India. *Biotropica* 29 (4): 489-500.
- Belshaw, R. and Bolton, B. 1993. The effect of forest disturbance on the leaf litter ant fauna in Ghana. *Biodiversity and Conservation* 2: 656-666.
- Bingham, C. T. 1903. The fauna of British India, including Ceylon and Burma. Hymenoptera, Vol. II. Ants and Cuckoo-wasps. London: Taylor and Francis.
- Bolton, B. 1994. Identification Guide to the Ant Genera of World. Cambridge: Harvard University Press.

- Byrne, M.M. 1994. Ecology of twig-dwelling ants in a wet lowland tropical forest. *Biotropica* 26: 16-72.
- Champion, H.G. and Seth, S.K. 1968. Revised Forest Types of India. New Delhi : Govt. of India Publications.
- Clough, E.A. 2004. Factors influencing Ant assemblages and ant Community composition in a Sub tropical-suburban Environment. Ph.D. thesis, Griffith University, USA.
- Coelho, I.R. and Ribeiro, S.P. 2006. Environment heterogeneity and seasonal effects in ground-dwelling ant (Hymenoptera: Formicidae) assemblages in the Parque Estadual do Rio Doce, MG, Brazil. *Neotropical Entomology* 35(1): 19-29.
- Davidson, D.W. 1977. Foraging Ecology and Community organization in Desert Seed-Eating Ants. *Ecology* 58 (4): 725-737.
- Fellers, J.H. 1989. Daily and seasonal activity in woodland ants. *Oecologia* 78: 69. Fellowes, J.R. 1996. Community composition of Hong Kong ants. Ph.D. thesis, University of Hong Kong, Hong Kong.
- Fisher, B.L. 2004. Diversity patterns of ants (Hymenoptera: Formicidae) along an elevational gradient on mounts Doudou in South-western Gabon. *California Academy of Sciences Memoir* 28: 269-286.
- Johnson, R.A. (1992) Soil texture as an influence on the distribution of the desert seed-harvester ants *Pogonomyrmex rugosus* and *Messor pergandei*. *Oecologia* 89:118-124.
- Levings, S.C. 1983. Seasonal, Annual and among-site variation in the ground ant community of a deciduous tropical forest : some causes of patchy species distribution. *Ecological Monograph* 5 (4): 435-455.
- Mavi, H.S. and Tiwana, D.S. 1993. Geography of Punjab. India: National Book Trust.
- Mittal, S.P., Aggarwal, R.K. and Samra, J.S. 2000. (eds.). Fifty years of Research on Sustainable Resource Management in Shivaliks Chandigarh : Central Soil and Water Conservation Research Centre, 506pp.
- Retana, J. and Cerda, X. 2000. Patterns of diversity and composition of Mediterranean ground ant communities tracking spatial and temporal variability in the thermal environment. *Oecologia* 123 (3): 436-443.
- Rico-Gray, V., Garcia-Franco, J.G., Palacios-Rios, M., Diaz-Castelazo, C., Parra-Table, V. and Navarro, J.A. 1998. Geographical and seasonal variation richness in the ant-plant interactions in Mexico. *Biotropica* 30: 190-200.
- Smith, T.M., Shugart, H.H. and Woodward, F.I. (eds.). 1997. Plant Functional Types: Their Relevance to Ecosystem Properties and Global Change. Cambridge: Cambridge University Press.
- Suwabe, M., Ohnishi, H., Kikuchi, K.K. and Tsuji, K. 2008. Difference in seasonal activity pattern between non-native and native ants in subtropical forest of Okinawa Island, Japan. *Ecological Research*, DOI 10.1007/s11284-008-0534-9.
- Tiwana, N.S. and Jerath, N. 2006. Biodiversity in the Shivalik Ecosystem of Punjab. Dehra Dun : Bishen Singh Mahendra Pal Singh.
- Touyama, Y. And Kameyama, T. 2004. Foraging activity of Argentine ant (*Linepithema humile*) in Japan during winter season, specially in relation with the temperature. *Edaphologia* 74: 27-34.
- Vanderwoude, C., De Bruyn L.A.L., House, A.P.N. 2000. Long-term ant community responses to selective harvesting of timber from spotted Gum (*Corymbia variegata*) dominated forests in South-east Queensland. *Ecological Management & Restoration* 1 (3): 204-214.
- Whitford, W. 1999. Seasonal and diurnal activity patterns in ant communities in a vegetation transition region of Southeastern New Mexico. *Sociobiology* 34 (3): 477-491.
- Zorilla, J.M., Serrano, J.M., Casado, M.A., Acosta, F.J. and Pineda, F.D. 1986. Structural characteristics of an ant community during succession. *Oikos* 47 (3): 346-354.